National Water Model for drought monitoring: a preliminary evaluation

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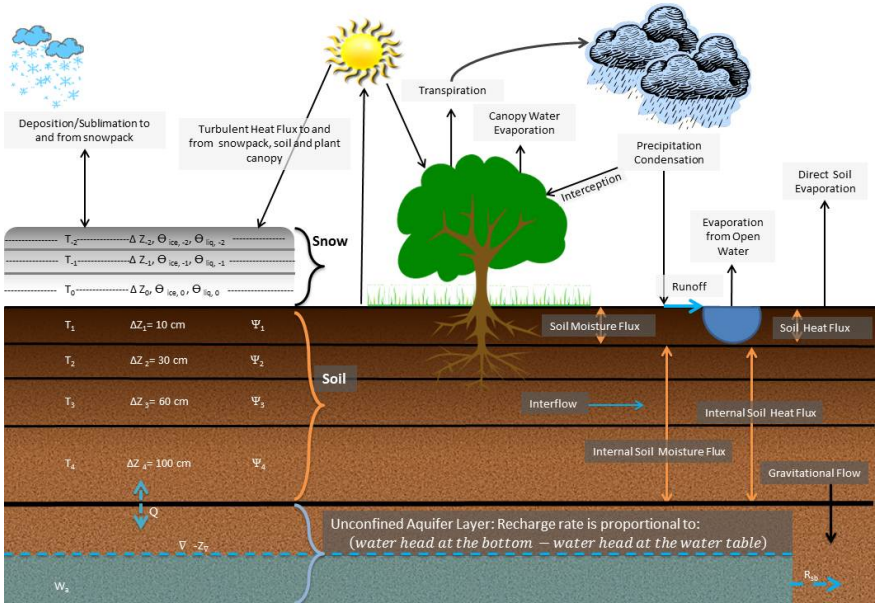
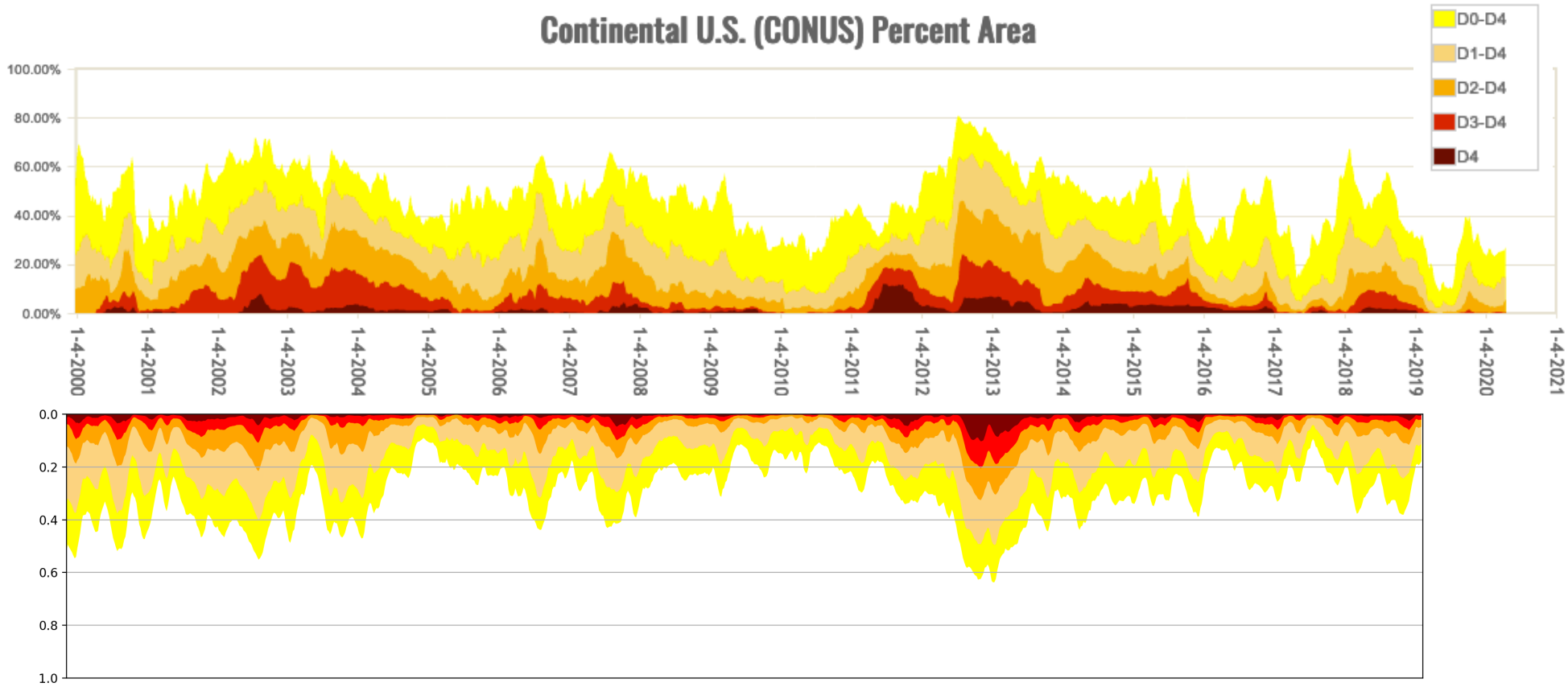
As one key innovation in the NOAA hydrological modelling, National Water Model (NWM) was recently upgraded to v2.0 in June 2019. The NWM could provide not only the streamflow prediction for hydrological guidance, but also the real-time high resolution land state analysis and assimilation. Based on the NWM v2.0 retrospective analysis from 1993 to 2018, we evaluated NWM soil moisture (SM) and evapotranspiration(ET) for the drought monitor application. The Soil Moisture Percentile (SMP) from NWM is compared with the official US drought monitor map in major drought events. The drought categories Dx based on NWM, is quantitively compared with similar drought monitor from the NLDAS2 ensemble. A long time-series soil moisture monitor from CPC leaky bucket model is compared against NWM, to distinguish the importance of the long temporal record vs high spatial resolution for drought monitor. The Evaporative Stress Index (ESI) based on ET estimation from NWM is also assessed for the rapid drought development, i.e. flush drought, to evaluate evapotranspiration for the drought development. The preliminary results indicated the NWM could well capture the major droughts during 2000 to 2018 and 2019 Southeast flash drought, show great potential in the future application for drought monitor.

National Water Model

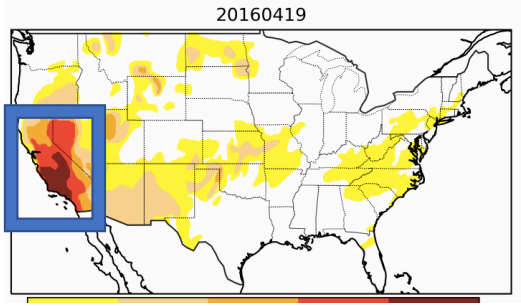
- Land: 1km, 4 layers, NoahMP model
- Real time
  - Tm00-02 3 members to form ensemble mean
  - Temporally aggregate hourly output to daily mean
  - Spatially aggregate to NLDAS 1/8 degree grid
  - Greatly reduce the data size to less than 1%
- Retrospective simulation
  - 1993-2018 total 26 years
  - Forced by NLDAS2 meteorological forcing
- Soil moisture percentile
  - Similar to NLDAS2 algorithm
    - concat. ~130-year SM CDF
  - Total column (0-200cm)
  - Top soil (0-40cm)

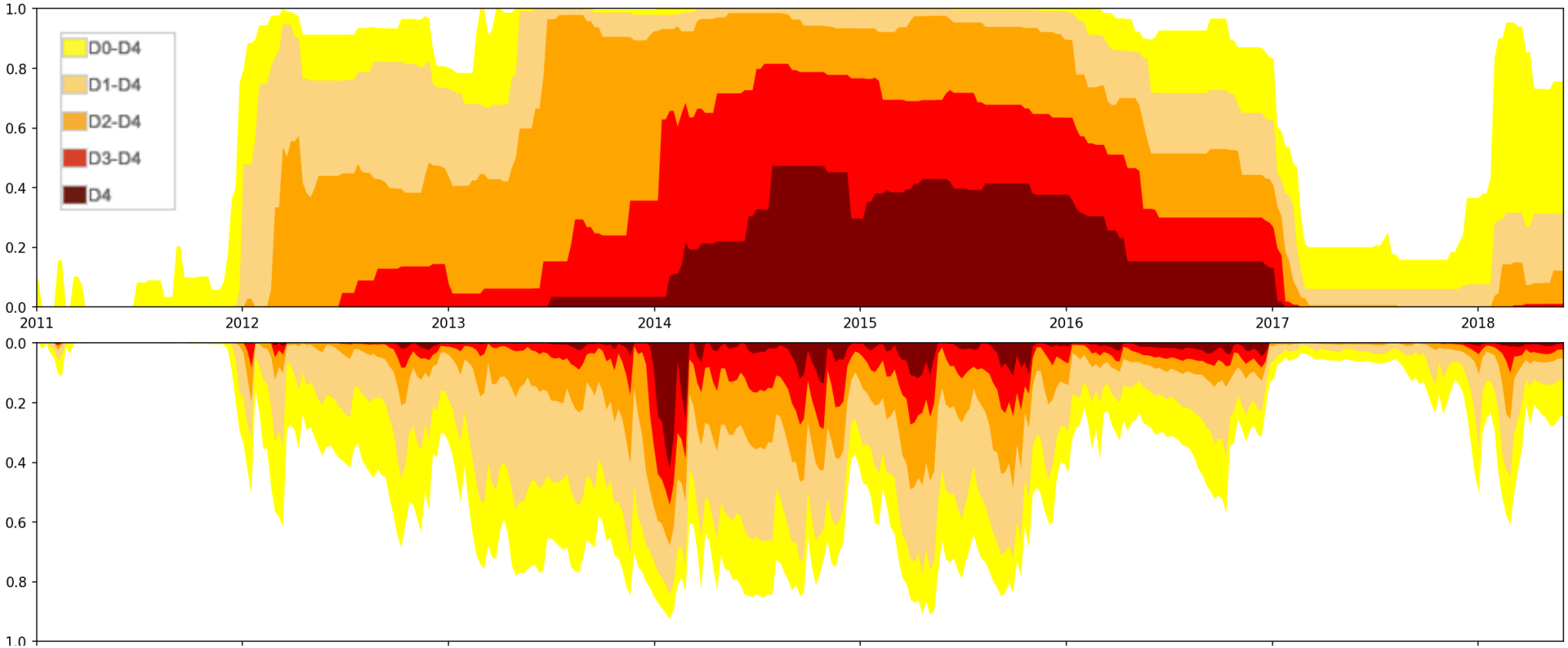




Based on the 29 days windows during 1993-2018 retrospective period

2012-2017 California drought

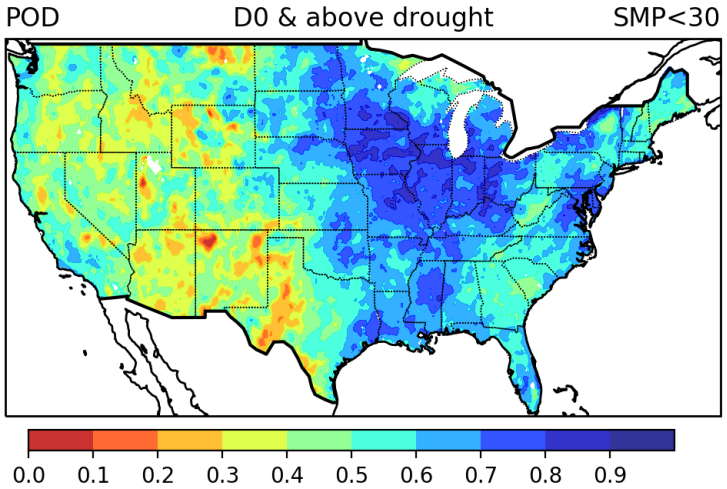


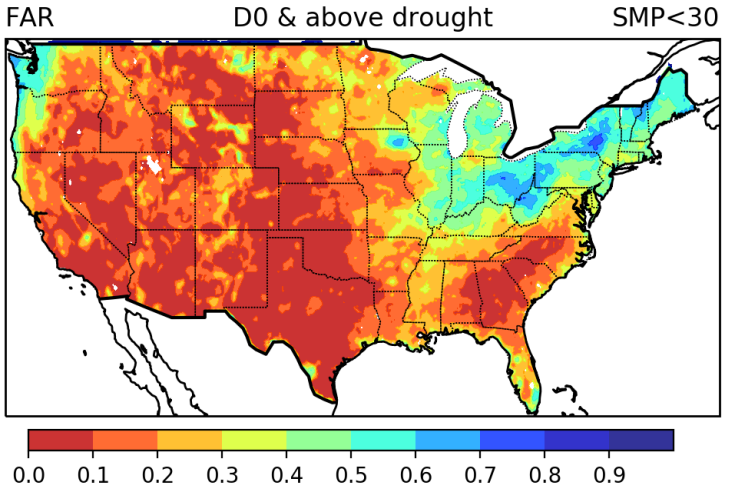


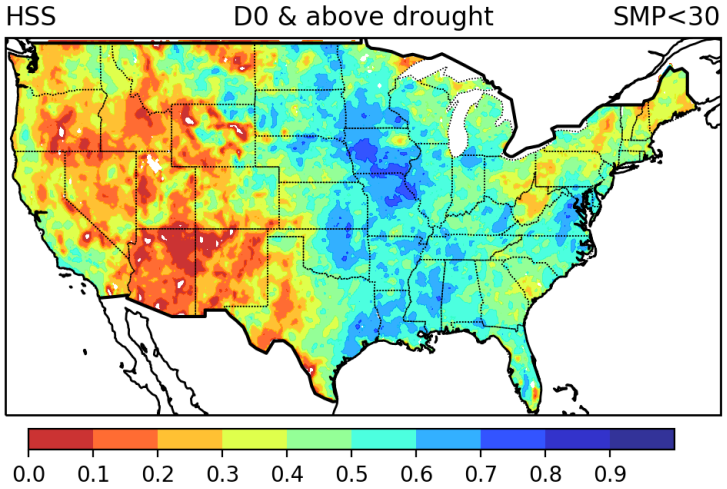
Contingency Table scores

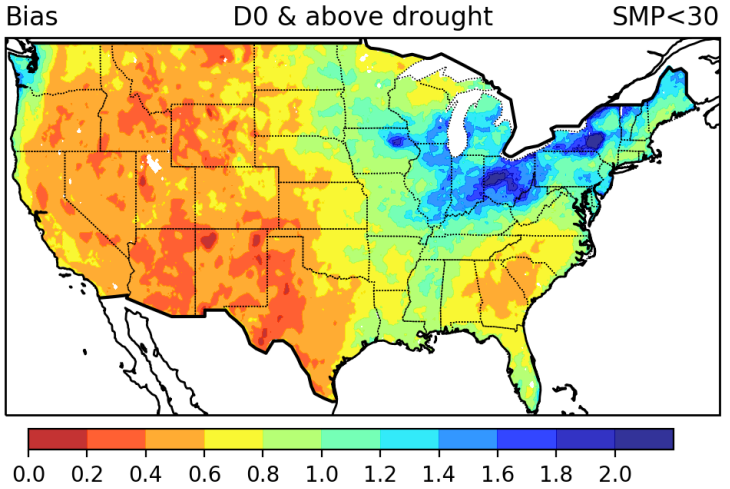
Event forecast	Event observed		
	Yes	No	Marginal total
Yes	a	b	a + b
No	c	d	c + d
Marginal total	a + c	b + d	a + b + c + d =n

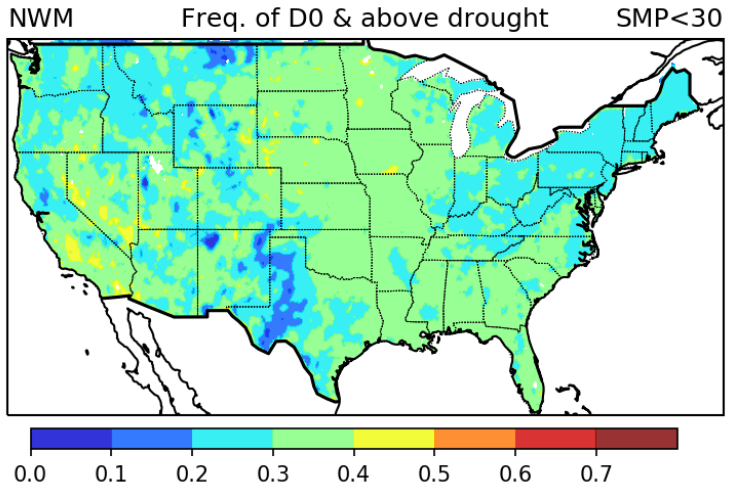
- POD (Probability of Detection) = a/(a+c) [correct warned events out of total observed events]
- FAR (False Alarm Ratio) = b/(a+b)
- CSI (critical success index) = a/(a+b+c) [correct warned events out of all warnings issued and unwarned events]
- Bias B= (a+b)/(a+c)
- Proportion correct PC = (a+d)/n
- Past Agreement PAG=a/(a+b)=1-FAR
- Heidke Skill Score (HSS)

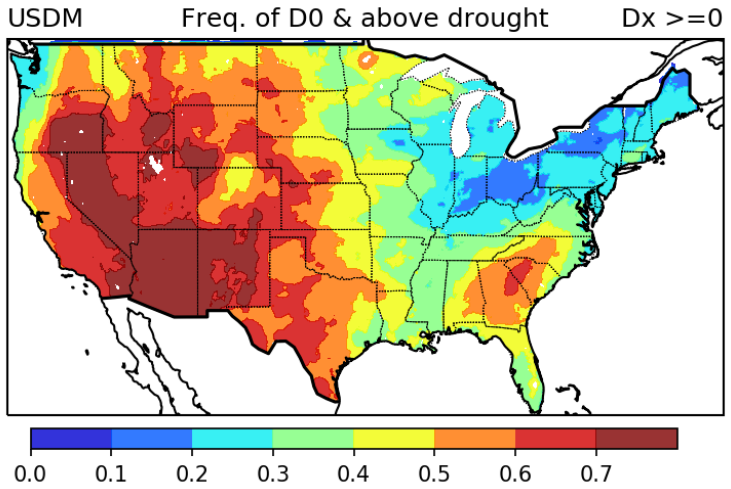

POD
D0 & above drought
SMP<30
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

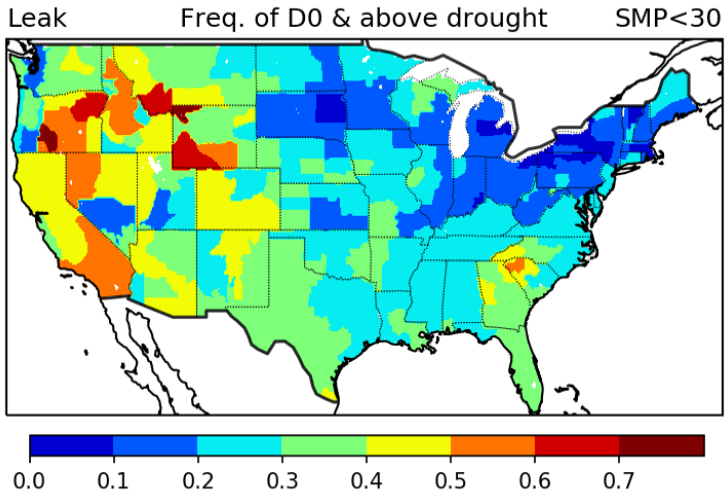

FAR
D0 & above drought
SMP<30
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

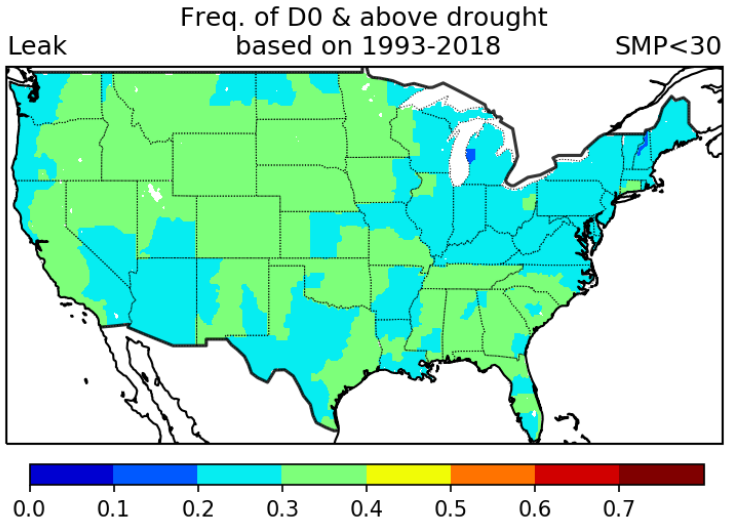

HSS
D0 & above drought
SMP<30
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9


Bias
D0 & above drought
SMP<30
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

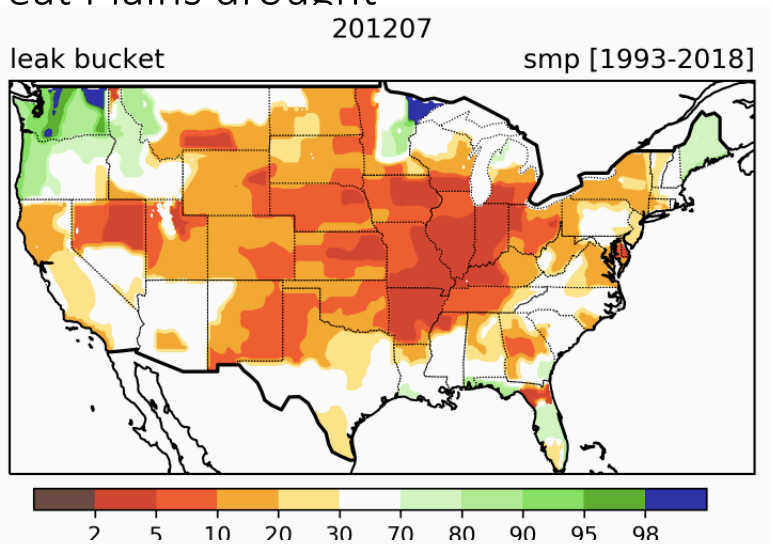

NWM
Freq. of D0 & above drought
SMP<30
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

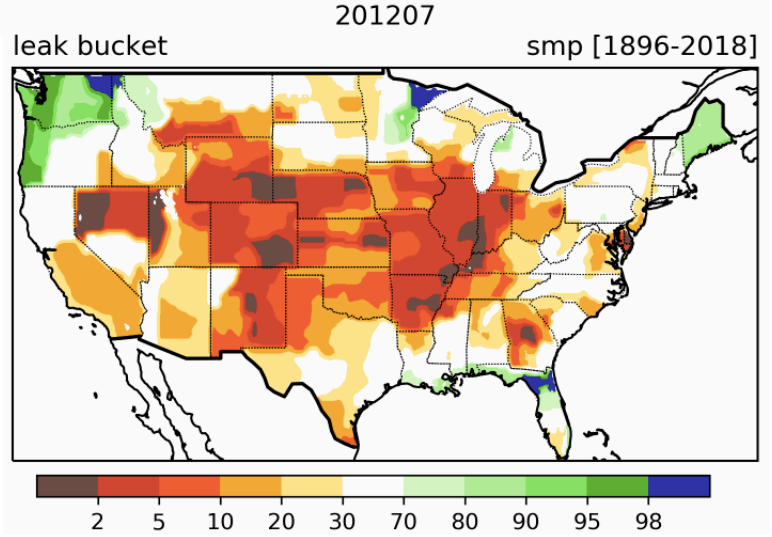

USDM
Freq. of D0 & above drought
Dx >=0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

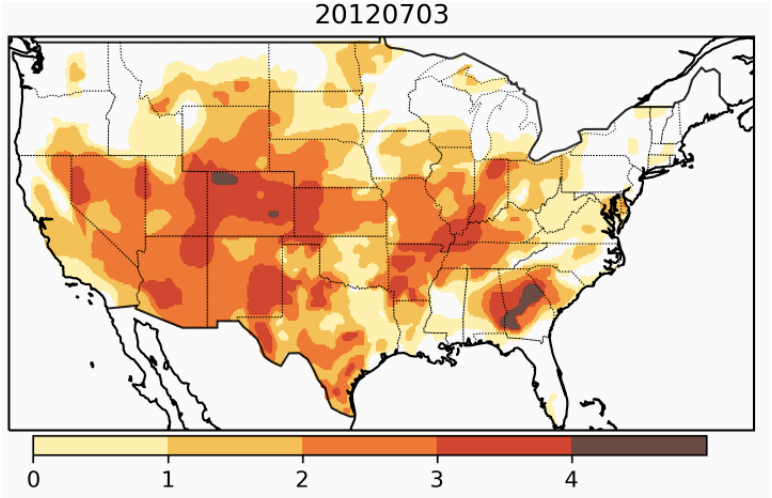

Leak
Freq. of D0 & above drought
SMP<30
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

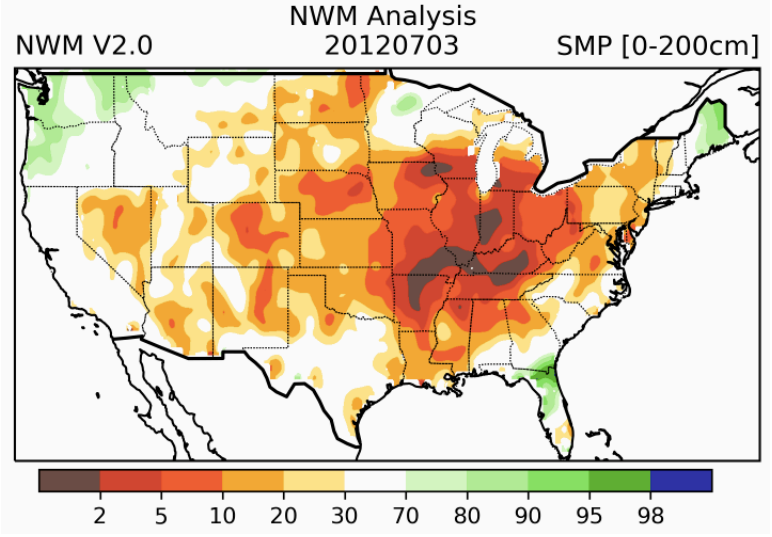

Leak
Freq. of D0 & above drought
based on 1993-2018
SMP<30
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

2012 Great Plains drought

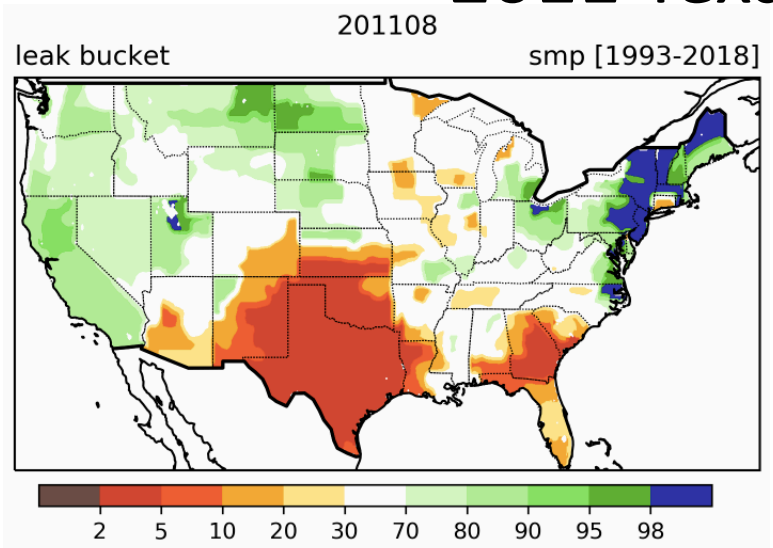


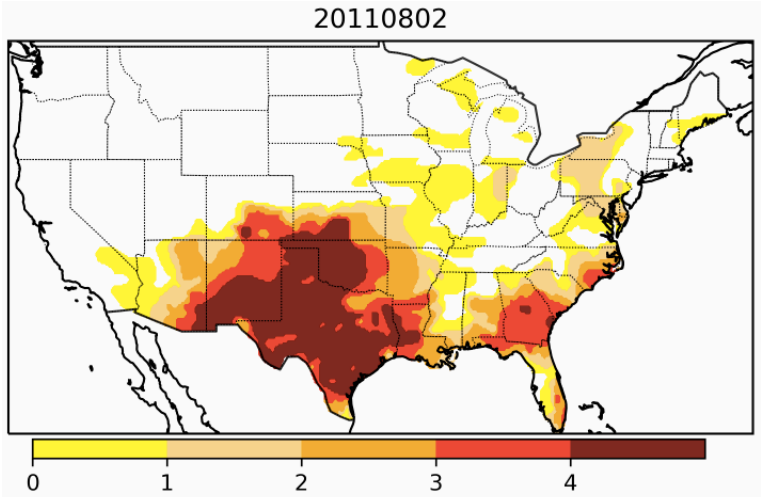


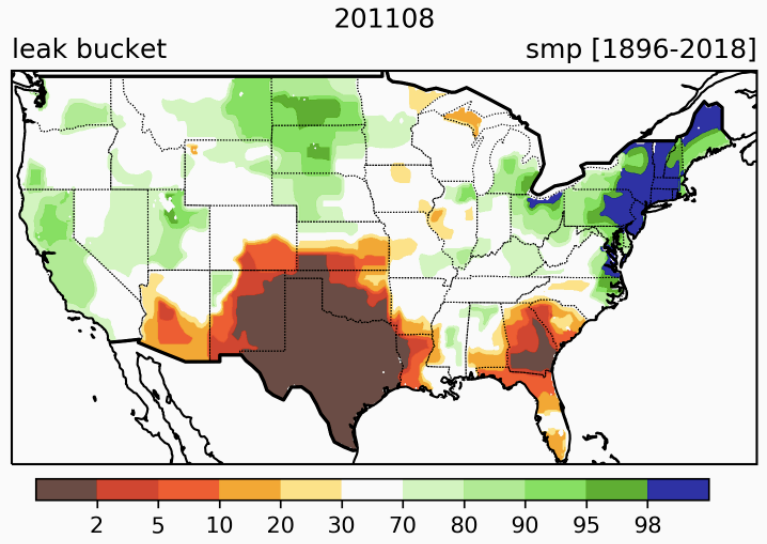


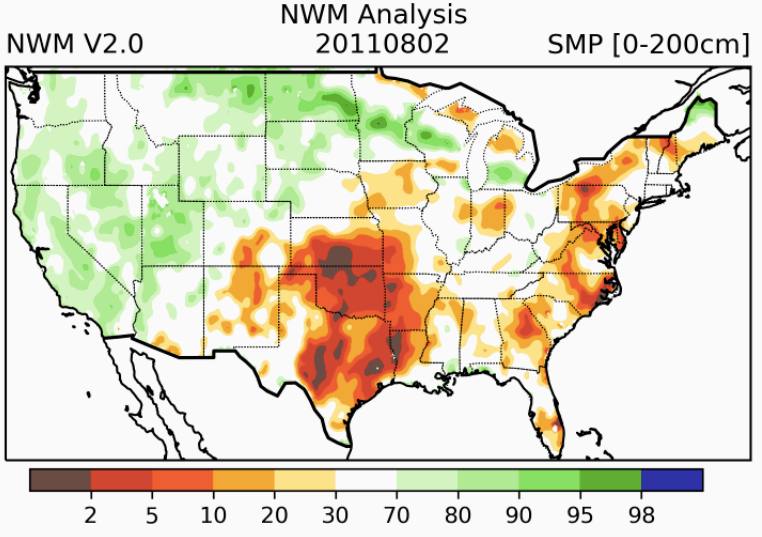


2011 Texas drought

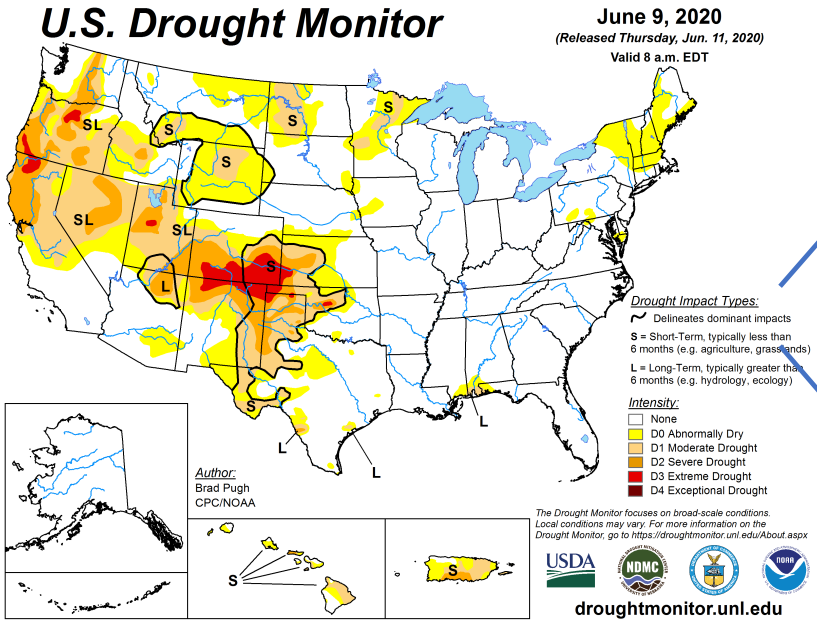


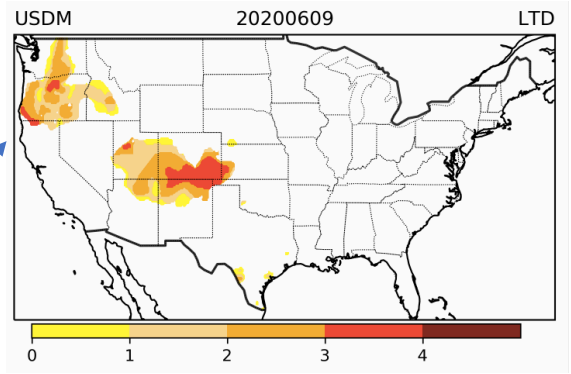


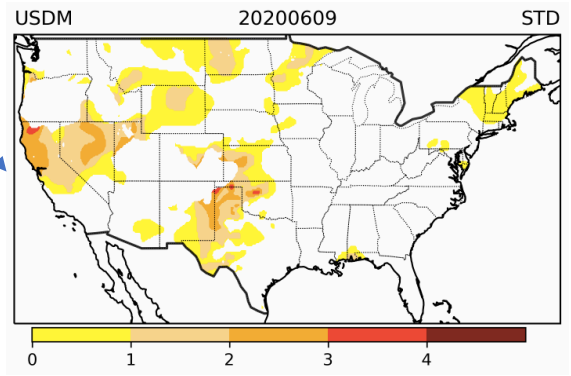




Separate the impact:

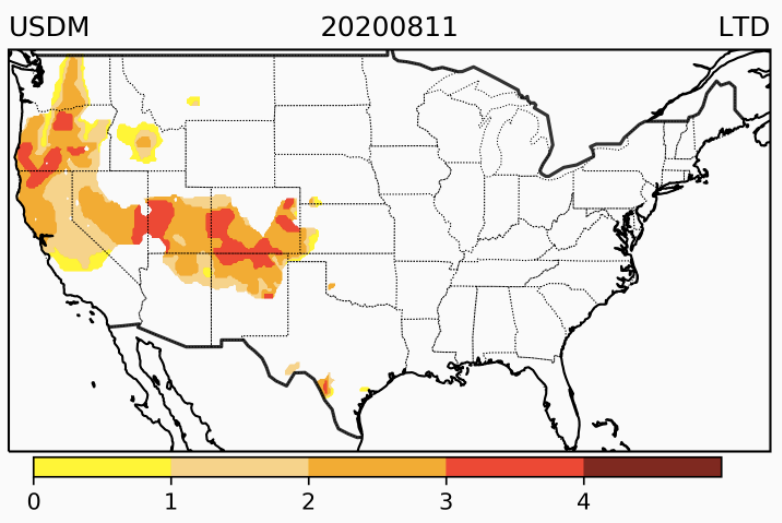


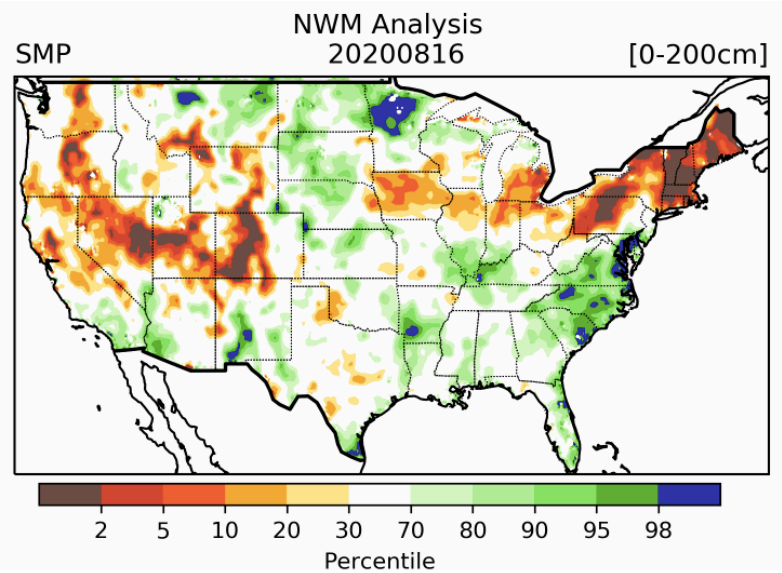




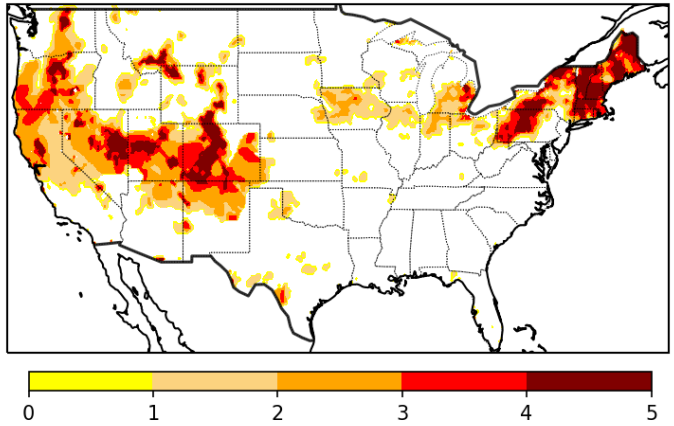
long term drought (LTD): persisted greater than 6 months
(past 26 weeks is D0-D4)

short term drought (STD): reminder, less than 6 months





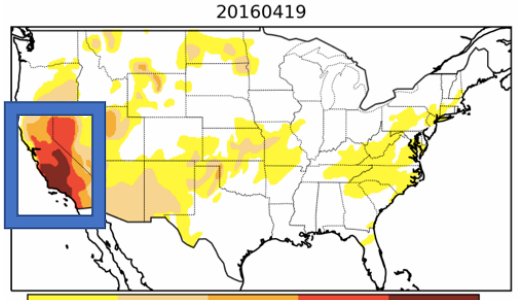
a merged NWM drought indicator

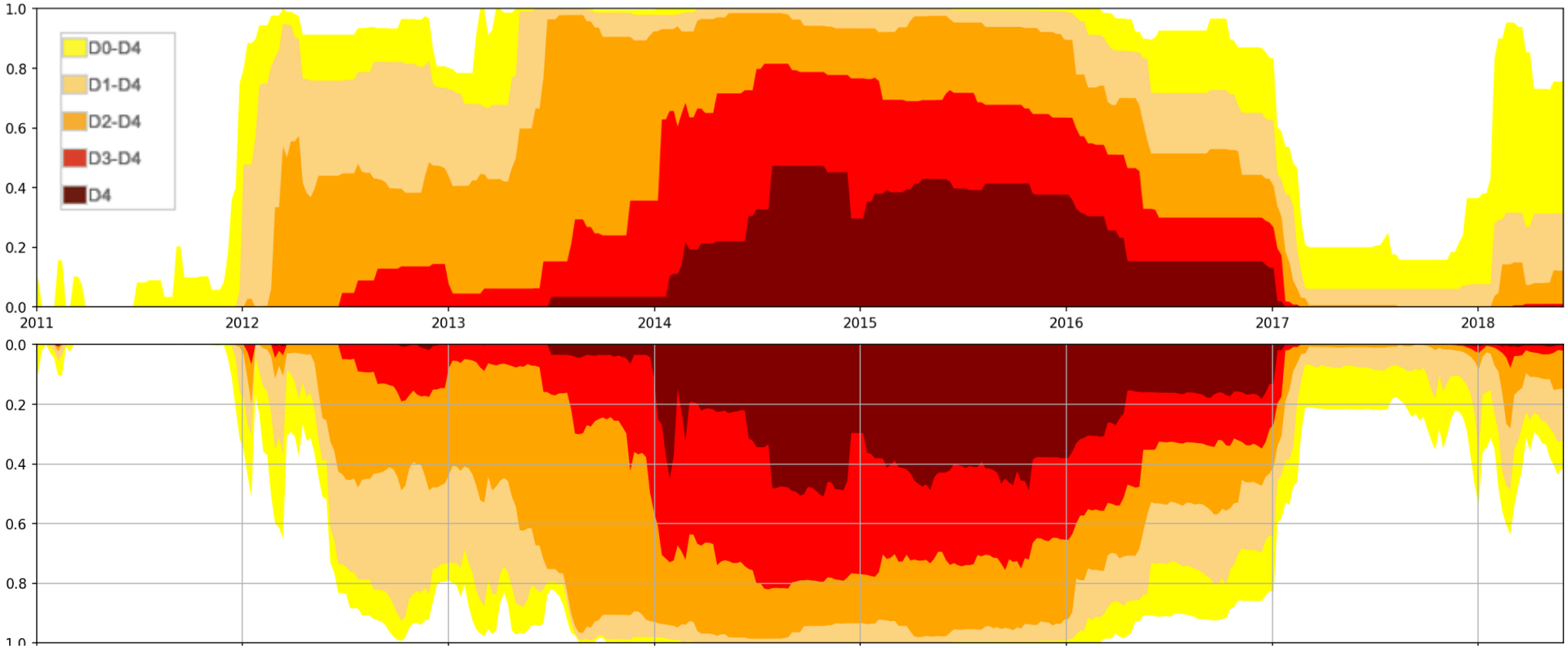


merge long-short term drought:

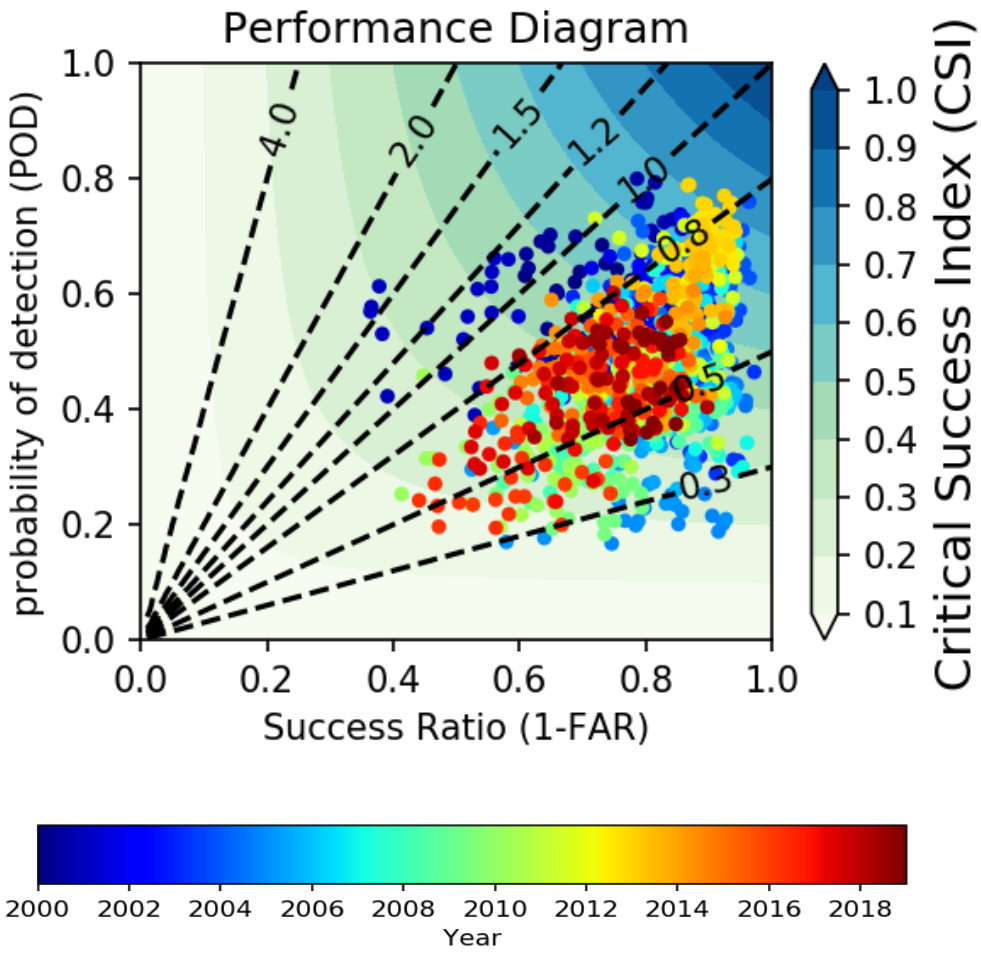
Empirical bivariate joint probability
(Hao and Aghakouchak 2014)

2012-2017 California drought

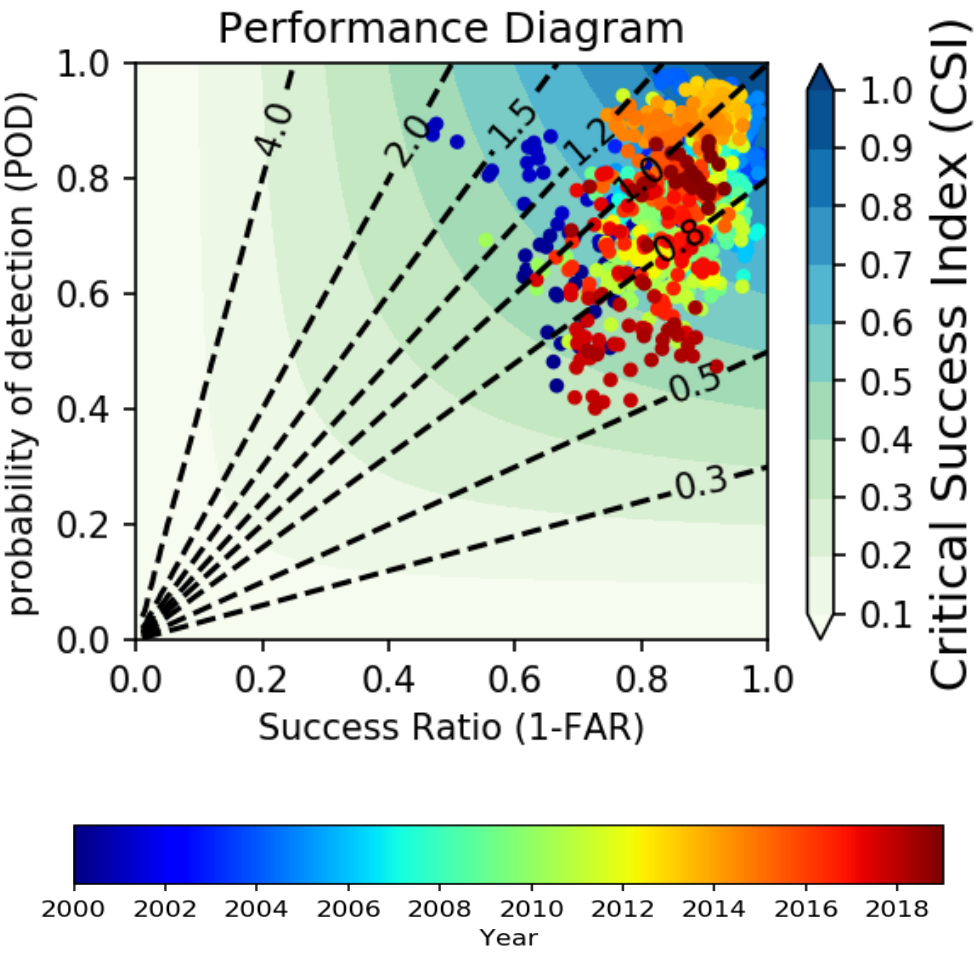


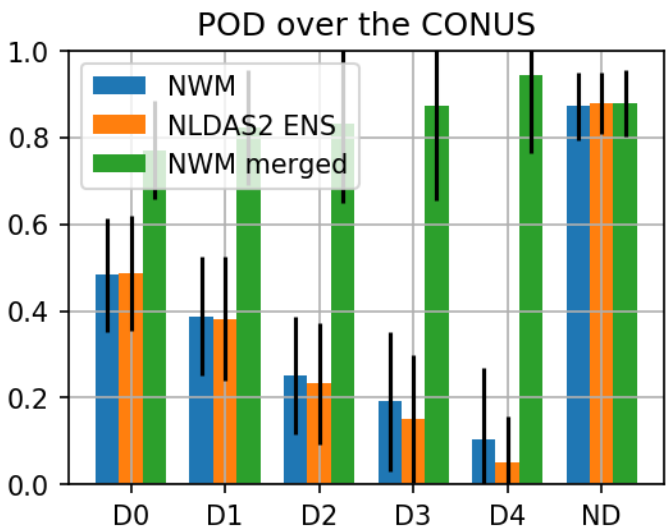


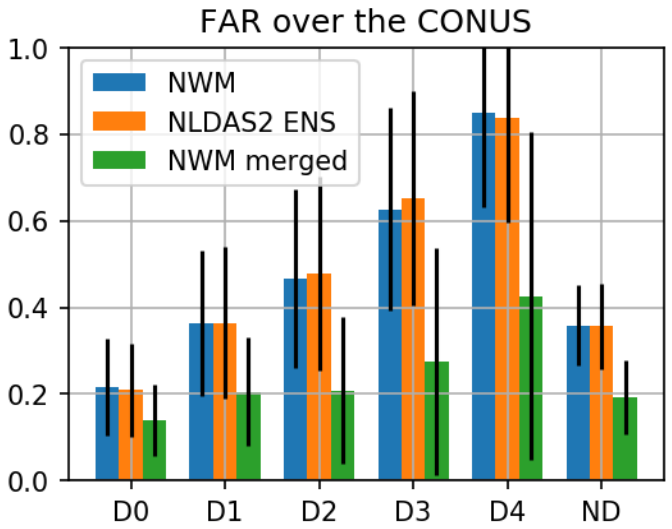
NWM SMP <30%

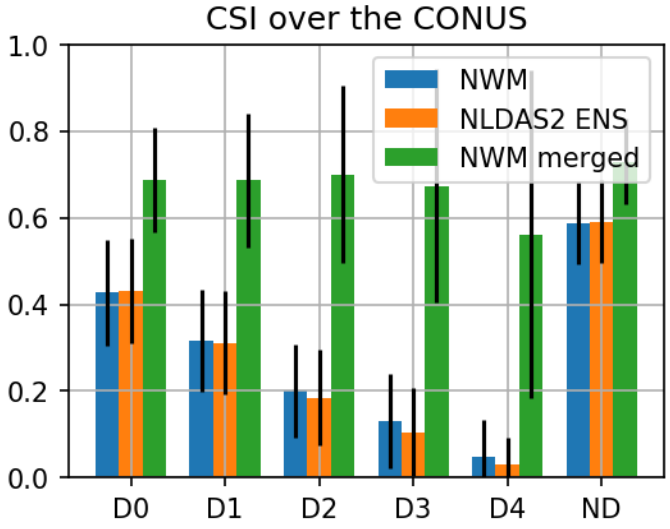


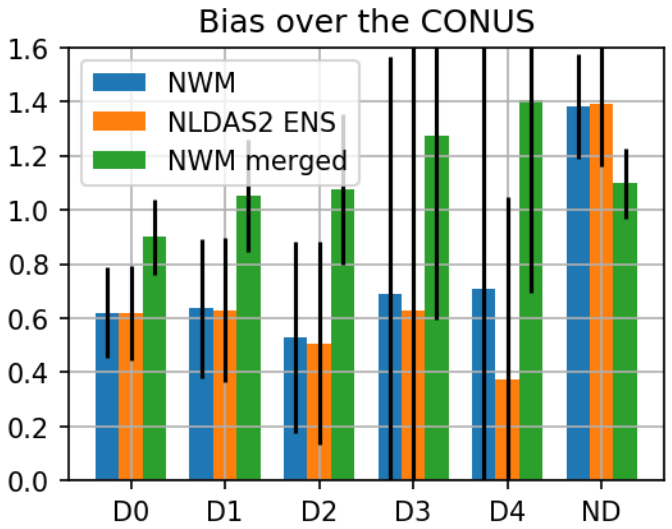
NWM merged SMP <30%




POD over the CONUS
NWM
NLDAS2 ENS
NWM merged
1.0
0.8
0.6
0.4
0.2
0.0
D0
D1
D2
D3
D4
ND

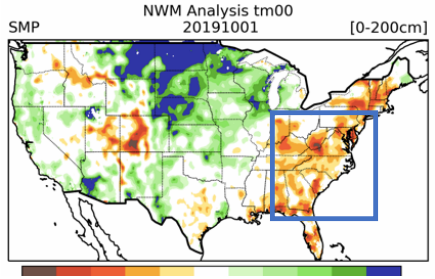

FAR over the CONUS
NWM
NLDAS2 ENS
NWM merged
1.0
0.8
0.6
0.4
0.2
0.0
D0
D1
D2
D3
D4
ND

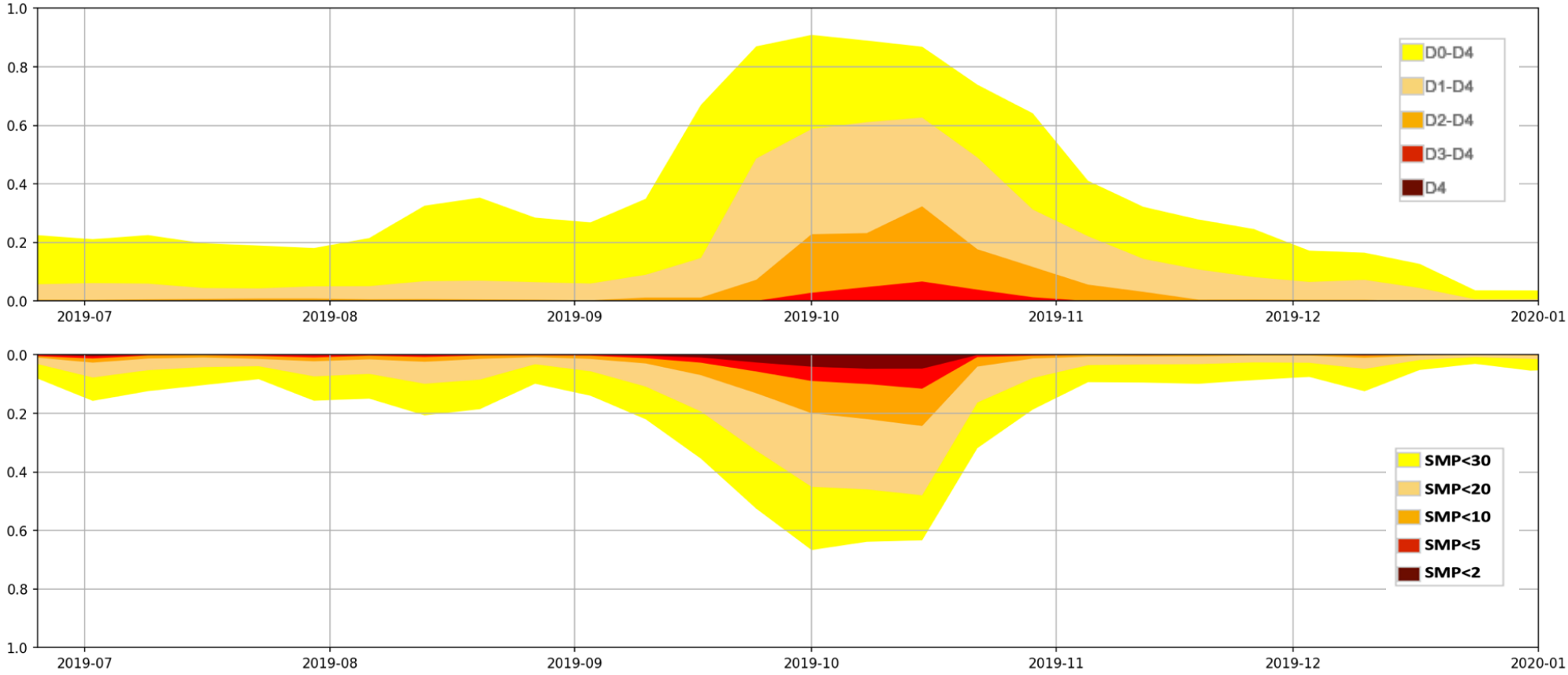

CSI over the CONUS
NWM
NLDAS2 ENS
NWM merged
1.0
0.8
0.6
0.4
0.2
0.0
D0
D1
D2
D3
D4
ND


Bias over the CONUS
NWM
NLDAS2 ENS
NWM merged
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
D0
D1
D2
D3
D4
ND

2019 SE flash drought

30-40E, 90-70W





Conclusions

- NWM v2.0 demonstrate great potential for drought monitoring
- NWM A&A cycle only delays a few hours compared with NLDAS2 four days, great reduced latency
- NWM 2.0 SMP map could well catch major drought events during retrospective period, but under-estimate drought intensity (Dx category).
- NWM could well detect the droughts In the eastern and central US. however, under-detect the long-term drought at Western US, based on the current retrospective period.
- NWM slightly improved in the detection of D2 and above droughts, compared with NLDAS2 multi-model ensemble. However, both models under-estimate the drought categories.
- The current 26 years NWM retrospective run is still too short for drought monitoring, compared with coarse resolution Leaking bucket model
- Merged with long-term drought from USDM, NWM could great improve the accuracy of NWM drought monitoring based on the Soil Moisture Percentile
- NWM well catch the 2019 SE flash drought